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Remote Handling and Evaluation Systems for Use in a Pyroprocess Research Facility

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- Summary

Background

- The construction of a pyroprocess research facility, called the PRIDE, has been recently completed, and is now being prepared for start-up operations

- All operations and maintenance of the process equipment must be performed remotely
  - Direct access by human operators to the in-cell is not possible during an operation due to the high toxicity of argon gas and nuclear materials
  - Designed to satisfy the requirements of remote operability and maintainability

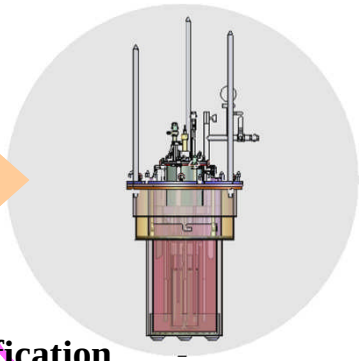
- To make such process equipments remotely operable and maintainable in the argon cell of PRIDE
  - Their design developments should be tested and evaluated in advance before they are constructed thereby improving the design completeness
  - Constructed process equipments should be also tested and evaluated before they are installed in situ, thereby improving the manufacturing completeness

Scenario for developing process equipment

3D models of Equipments for Pyroprocessing

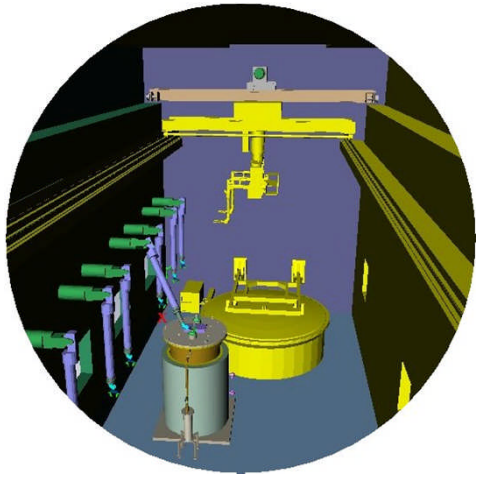
Design

Evaluating Remote Operability/Maintainability of 3D Models of Equipments



modification

Evaluation



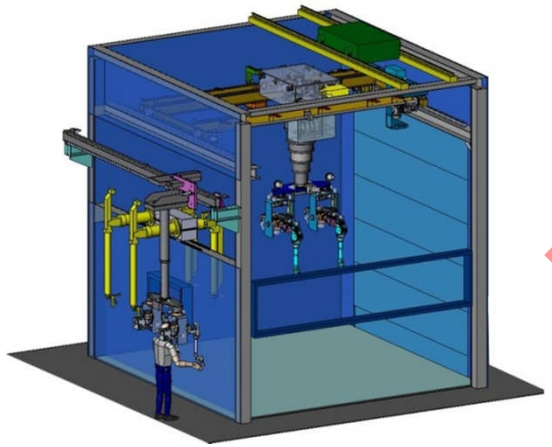
Simulator
Digital Mock-up of PRIDE

Construction

Evaluating remote Operability/Maintainability of Constructed Equipments

modification

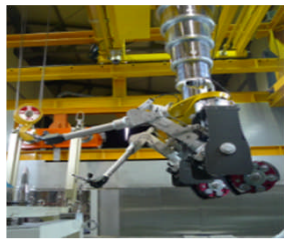
Evaluation



Remote Handling Evaluation Mock-up of PRIDE

Installation

PRIDE



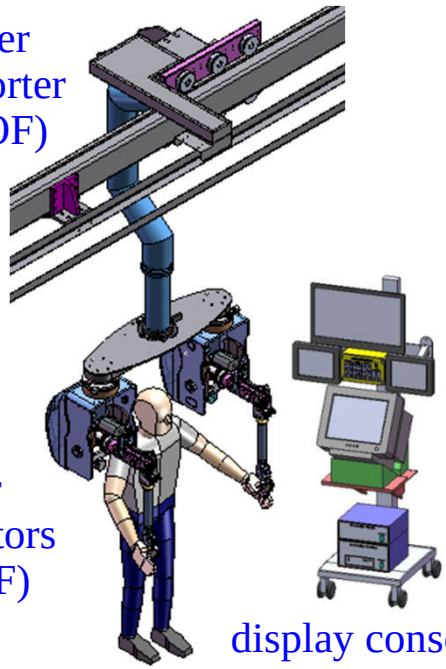
Remote handling system

I. BDSM (1/4) – R&D Scope

BDSM: Bridge transported Dual arm Servo-Manipulator System

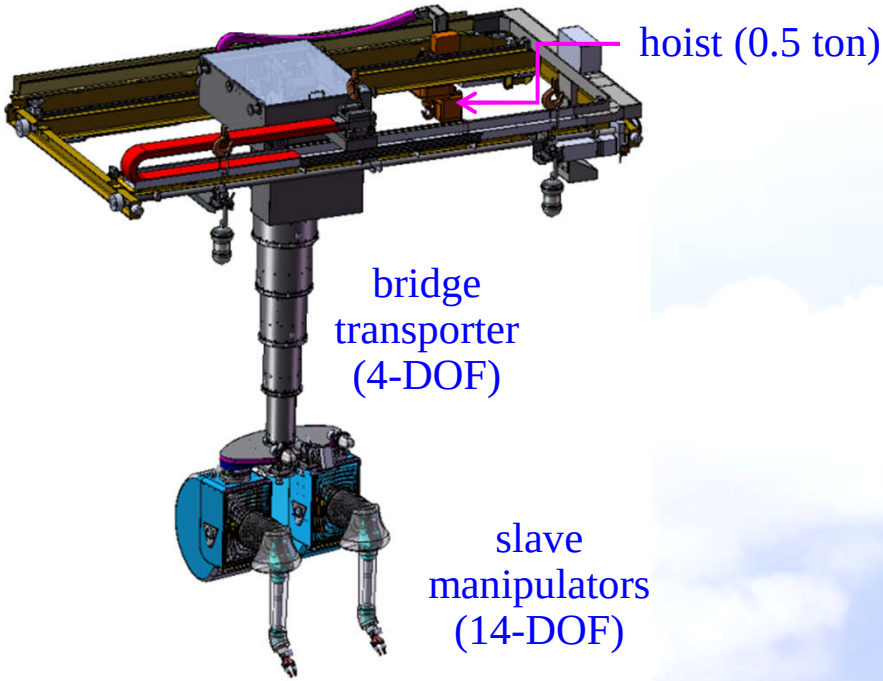
- **Developed to achieve a dexterous manipulation**
- **Bridge Transporter**
- **Dual arm master-slave servo-manipulators**
- **DSP-based remote control system for accurate and reliable servo-control**

Out-of-cell



Cell wall

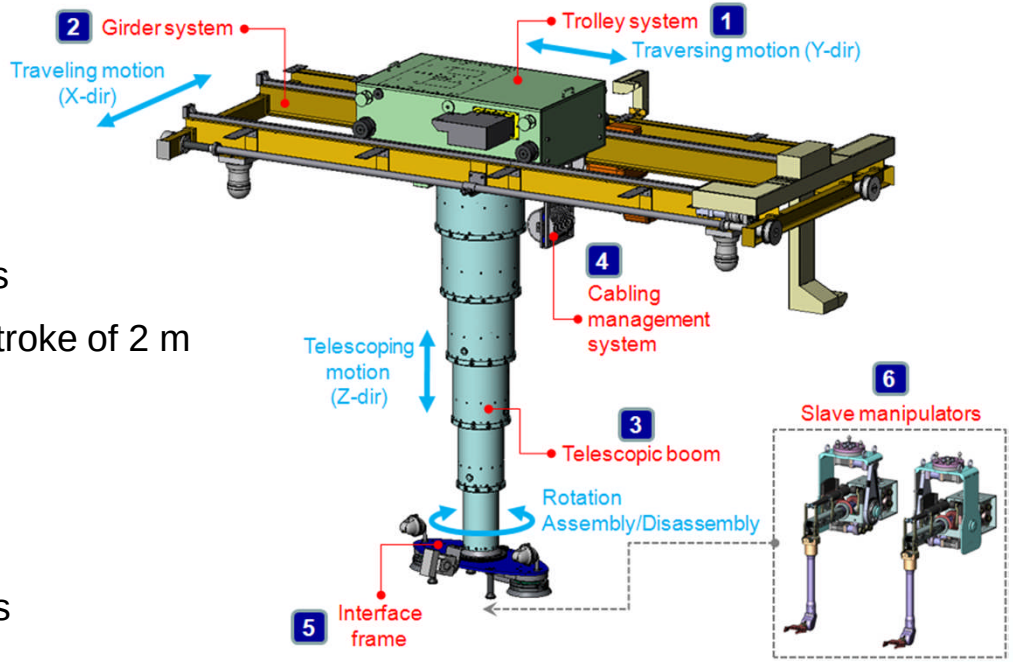
In-cell

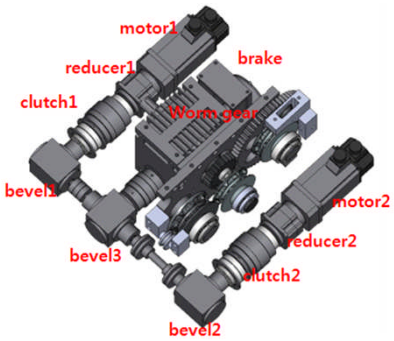


I. BDSM (2/4) – Bridge Transporter

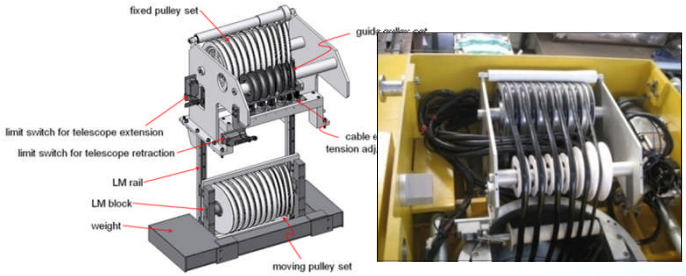
Technical features

- 4-DOF: 3 Cartesian + 1 rotation
- Telescopic boom
  - Pipe not plate: high bending and torsion stiffness
  - Equally extensible telescoping motion with the stroke of 2 m
  - Sealed with bellows –type boots
- Driving line duplication
- Cable management system
  - Compact design to manage 6-customized cables
  - Any type of telescope can be synchronized
- Max. speed: 7.3 (X), 5.7 (Y), 1.9 (Z) m/min

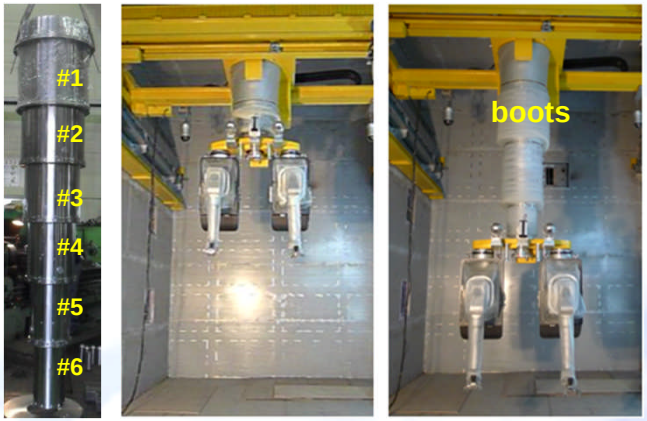




Telescopic motion module



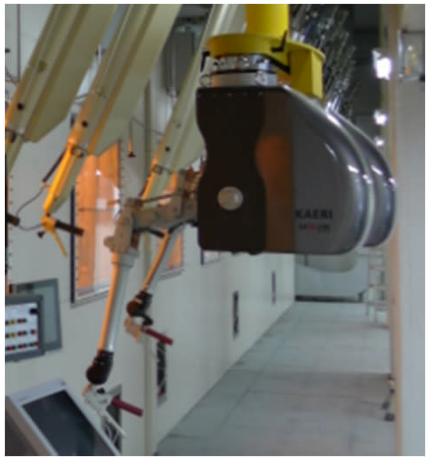
Cable management system



Telescopic boom retracted, extended

I. BDSM (3/4) – M/S servo-manipulators

In-cell BDSM



Out-of-cell BDSM

Control & display system

Specification of the BDSM

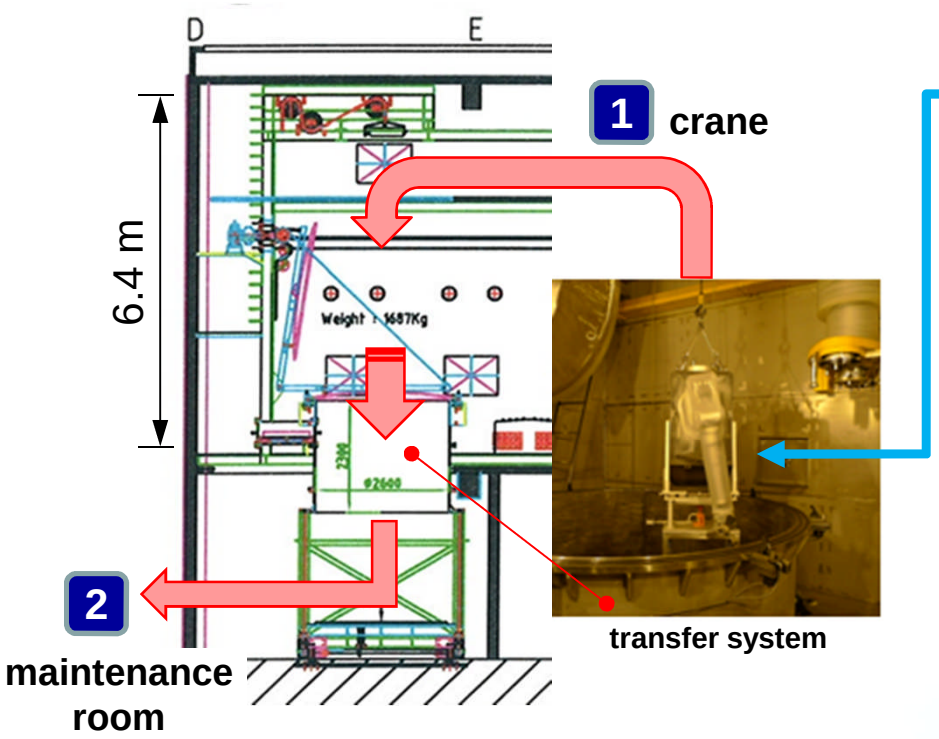
Mechanical specifications (replica type)		
Degree of freedom		6 + gripper/handle
Load capacity (slave)		250 N (continuous)
Force feedback capacity (master)		50 N (continuous)
Upper arm	incline (axis 1)	± 45˚
	rotation (axis 2)	± 45˚
	length (mm)	375 (master) / 600 (slave)
Forearm	incline (axis 3)	± 45˚
	rotation (axis 4)	± 110˚
	length (mm)	500 (master) / 800 (slave)
Wrist	incline (axis 5)	+37 ~ -143˚
	rotation (axis 6)	± 170˚
Grip opening width (mm)		0 ~ 100
Reach (master/slave)		0.95 m / 1.56 m
Total weight (master/slave)		45 kg / 165 kg
Power transmission		Gear/belt (#1), cable(#2~#7)
Contamination protection		Boots, cover
Electrical/Control specifications		
Motor type		BLDC with resolver
Motion control hardware		DSP controller
Motion control software		GUI (PD), firmware (DSP)
Control algorithm		PD, PID, TDC
Camera system		7 set with display system

I. BDSM (4/4) - Remote maintenance

Interface system

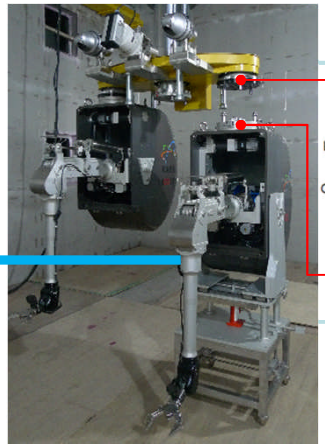
- For maintenance
- Platform for multi-purpose robotic tools
  - Reconfigurable; easily extended to other applications
  - Safe transfer and accurate positioning

Transfer procedures of a slave manipulator

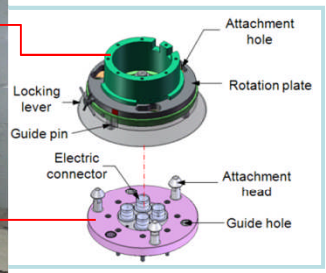


Maintenance of BDSM modules

- Interface system: for both mech. & electrical connections
- Modules: trolley, manipulator, cameras, tools, etc.
- Tools: MSM, crane



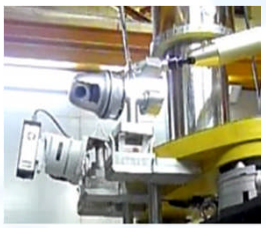
slave manipulator



interface system

trolley

robotic tool

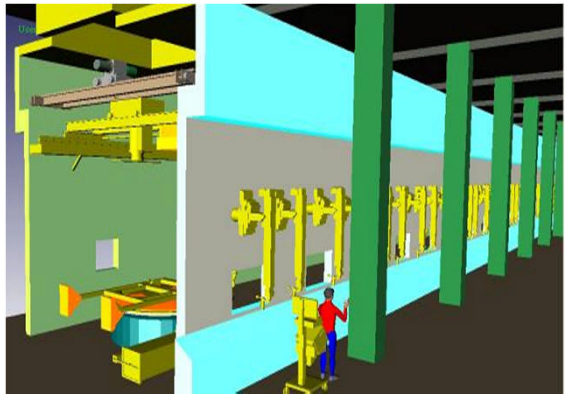


camera

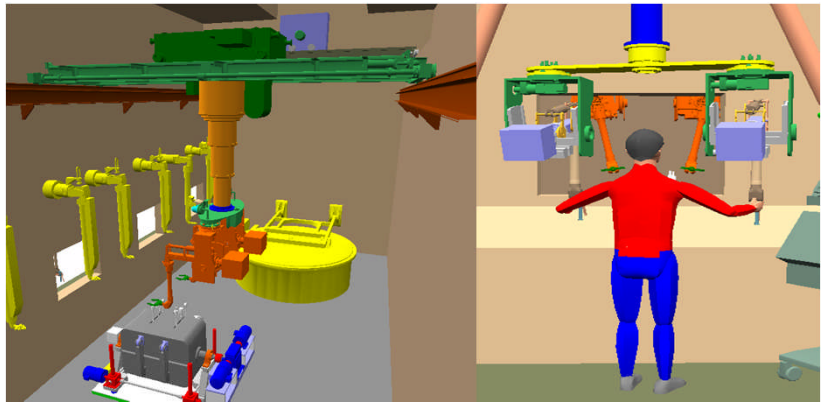
connector

II. Simulator (1/3) - Overview

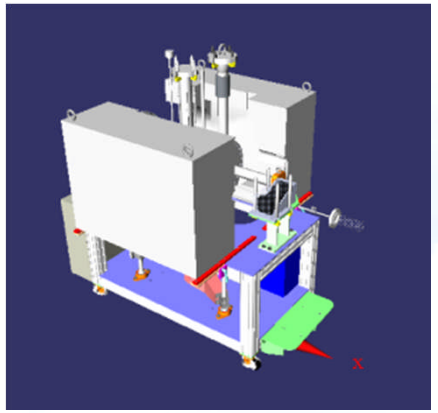
- Prototype of a haptic simulator
- Remote evaluation tool in a full-scale digital mock-up (virtual facility) of the PRIDE
- Provide an efficient means for simulating and verifying the conceptual design, design developments, arrangements, and rehearsal of pyroprocessing equipment in a virtual environment in advance



Geometry of virtual PRIDE

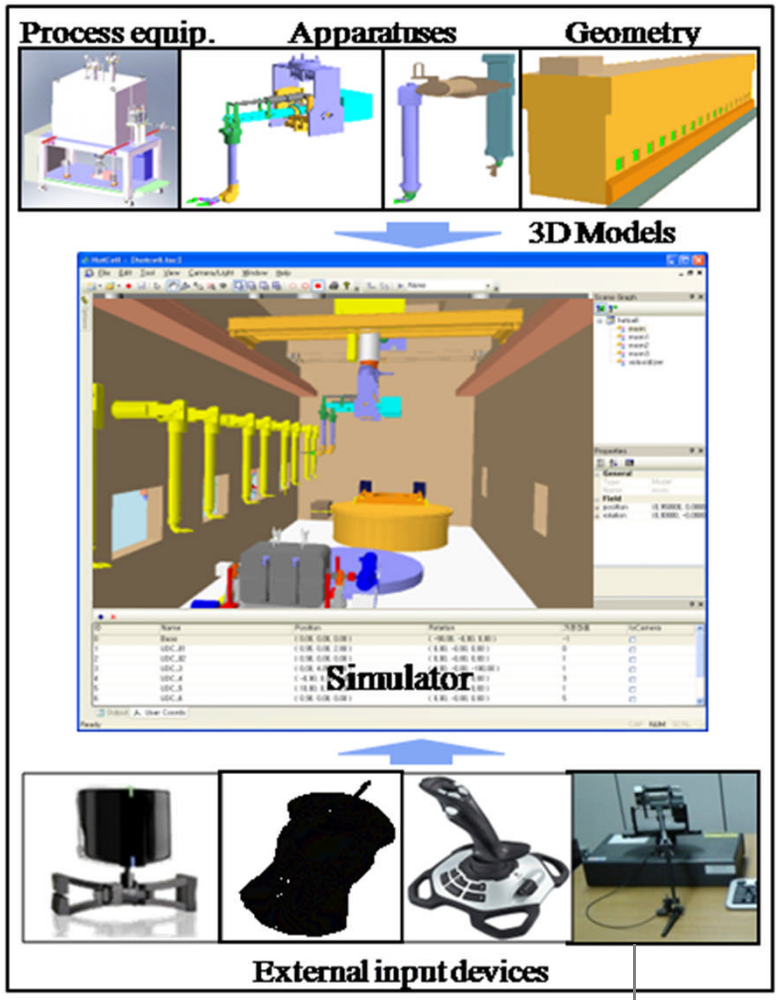


Apparatus of virtual MSM, BDSM and crane



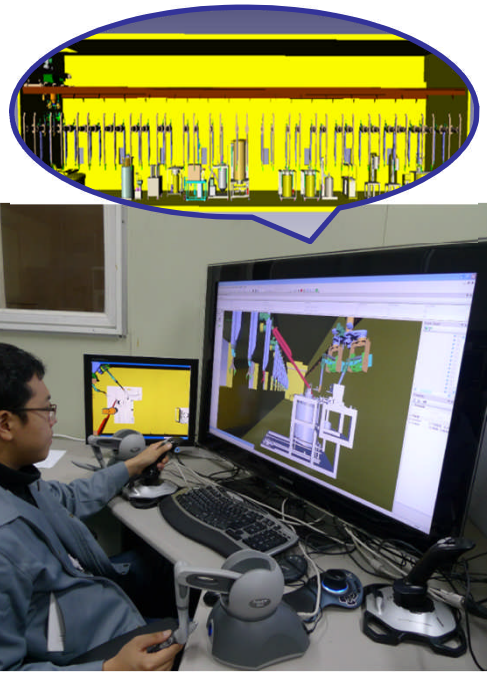
Process equipment of virtual voloxidizer

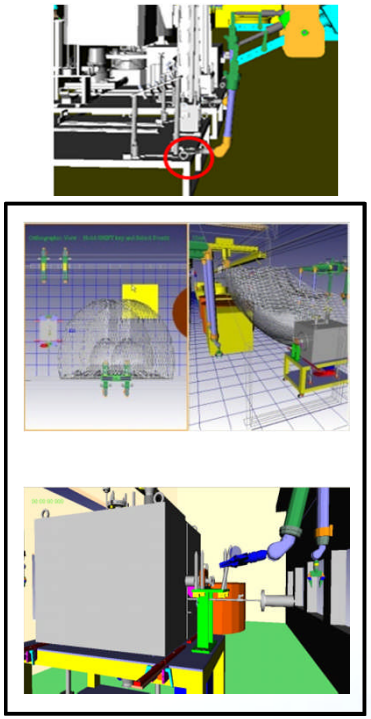
II. Simulator (2/3) - Constitution



Interaction media between operator and virtual apparatuses

Virtual PRIDE
(PRIDE Digital Mock-up)

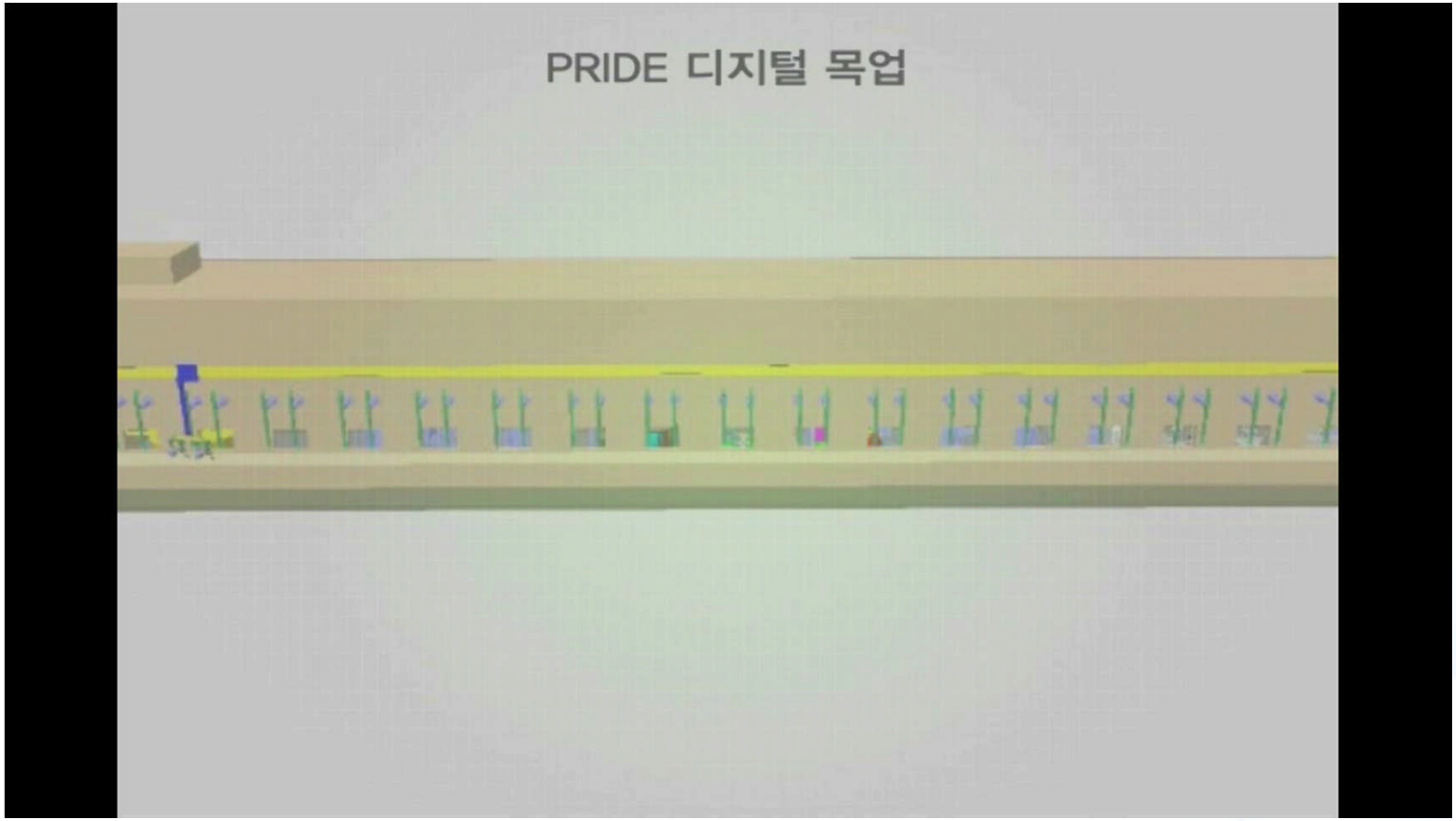




Evaluation of Process Equipments

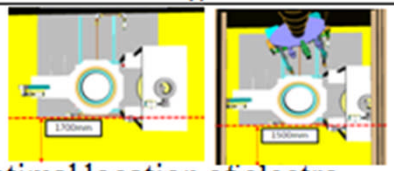
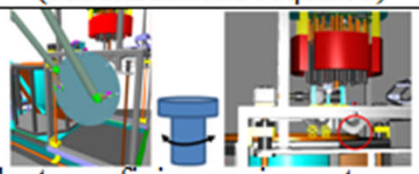
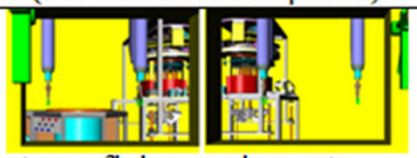
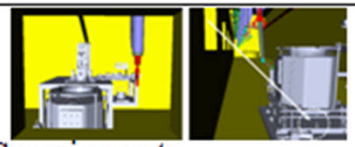
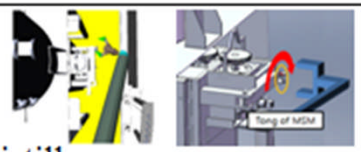
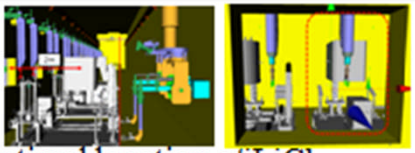
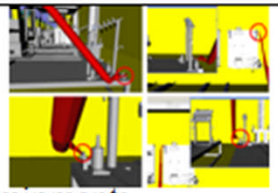
- From a model viewpoint
  - Virtual PRIDE consists of geometry, apparatuses, and process equipments modeled by software
  - Geometry: argon cell of PRIDE
  - Apparatuses (MSM, BDSM, overhead crane, auxiliary devices or tools) are linked to external input devices
  - Process equipments: electrolytic reduction , electro-refining, electro-wining, and waste salt treatment systems

Video 1. Simulator



II. Simulator (3/3) - Evaluation of Design Models

Evaluation Results

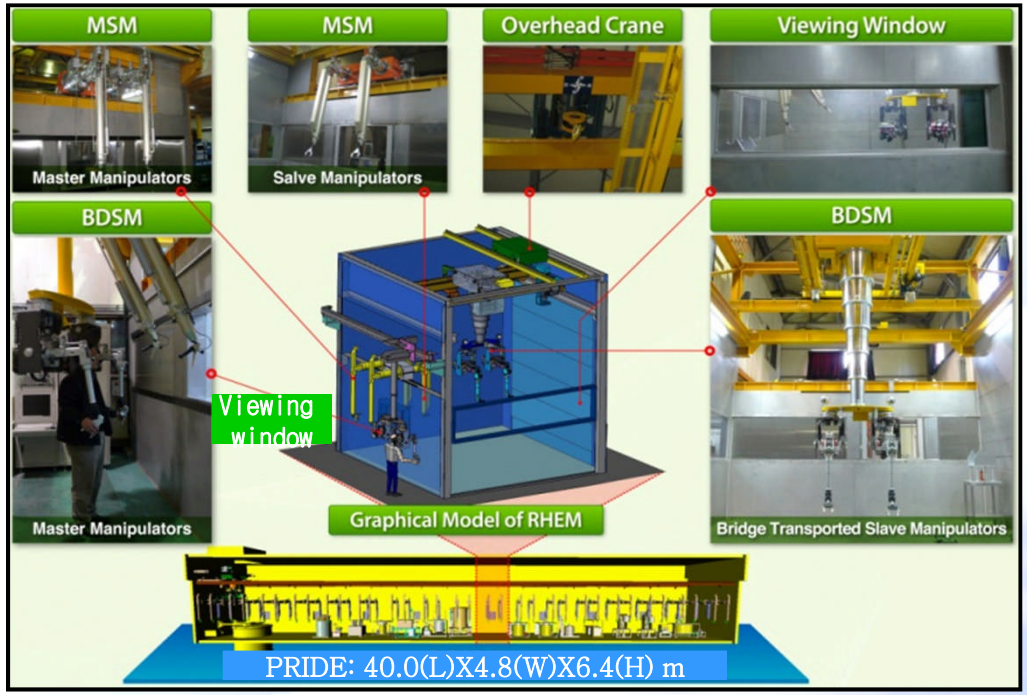
3D models of equipments	Accessibility or Arrangements	Remote operability (Modifications required)	Remote maintainability (Modifications required)
Electro-refining process	 Optimal location of electro-refining equipment - Front face to be located at distance between 1.2 and 1.5 m apart from an operating window	 Electro-refining equipment: - Redesigning handles for lifting and moving a upper cover from a viewpoint of MSM's tongs or crane - Vertical stroke of flange holder to be increased	 Electro-refining equipment: - Redesigning and relocating a motor module for exchanging anode basket so that, when flange is at its top position, it is visualized and handled by MSM and BDSM
Electro-winning process	 Optimal location of LCC equipment: - Center position to be located at 0.8 m apart from an operating window	 LCC equipment: - Making the size of guides taller - Vision to be secured	 Cd distiller - Making the size of handle for securing driving motors bigger - Vision to be secured
Waste salt regeneration & solidification process	 Optimal location of LiCl equipment: - Center position to be located at 2 m apart from an operating window	 LiCl equipment: - Vision to be secured - Redesigning a shape of handle from a viewpoint of MSM's tongs - Use of motor with brake for holding a rotary device when rotated	 LiCl equipment: - Changing positions of lifting rings located at rear part of a base frame - Considering a center of gravity of lifting rings located at upper part of heating module

III. RHEM (1/2) - Overview

- Usage
  - Useful means for testing and evaluating the operability and maintainability of constructed pyroprocessing equipments in advance at the same operating conditions of the PRIDE from the remote handling viewpoint before they are installed in the PRIDE
  - Utilization in improving the completeness and reliability of the pyroprocessing equipments to be used at the PRIDE

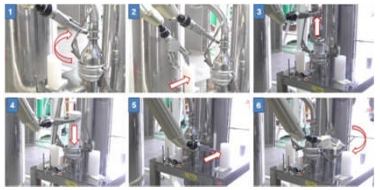
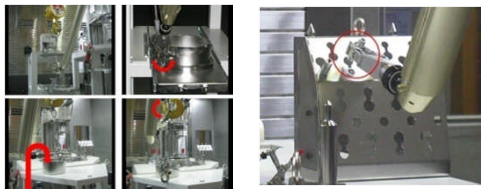
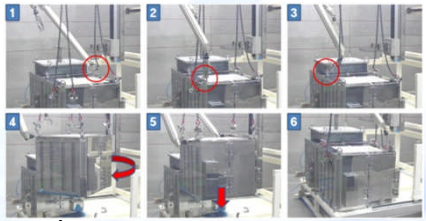
- Features
  - 1/8 scale-downed mock-up of the PRIDE in length with the same width and height as ones of the PRIDE, but air atmosphere
  - Configuration of 5.0x4.8x6.4 (LxWxH) m

- Consiting of
  - One BDSM
  - Two pairs of MSM
  - One overhead crane (two tons)
  - One flexible viewing window



III. RHEM (2/2) – Evaluation of Constructed Equi.

Evaluation Results - Mock-ups of Process Equipments

3D models of equipments	Accessibility or Arrangements	Remote operability (Modifications recommended)	Remote maintainability (Modifications recommended)
Electrolytic reduction process	 Optimal location of Cathode Process (CP) equipment - Not defined	 CP equipment: -Tightening/Loosening flange screws possible but minimizing impact to MSM and BDSM due to vibration of impact wrench	 CP equipment : Cold Trap device -Connecting a pipe of Cold Trap device to CP equip. possible and also disconnecting it from CP equip. possible by using both MSM and BDSM
Electro-winning process	 Optimal location of RAR equipment: - Center position to be located at 1.8 m apart from an operating window	 RAR equipment: - Changing a shape of a handle into a circle - Leveling a position of a handle at the upper part of a vessel - Considering a guide for assembling and disassembling electric connectors	 RAR equipment -Preventing a motor from falling down during operation -Improving a handle necessary for fastening and loosing a motor frame
Waste salt regeneration & solidification process	 Optimal location of Melting equipment: -Center position to be located at 1.3 m apart from an operating window	 Melting equipment: - Forward/backward movements possible - Recommending the mounting of a grip to the body frame for ease movements by using MSM	 Melting equipment: - Inaccessible to a holding ring for dismantling a heater and need adjusting the height and position of a holding ring

Video 2. BDSM & RHEM

Summary

- Described is a way of evaluating and improving the design and construction of process equipments
- Remote operability and maintainability of 3D design models of process equipments were tested and evaluated by using a developed simulator, and results were fed back to developers.
- Remote operability and maintainability of constructed mock-ups of process equipments were tested and evaluated by using RHEM, and results were also fed back to developer.
- Evaluation techniques used for improving process equipments from the viewpoint of remote operability and maintainability will have benefits of
  - improved design completeness, and
  - Improved construction completeness

Thank you for your attention.